DOCKET NO.
HIT1P035/HSJ9-2003-0154US1

U.S. PATENT APPLICATION

FOR

TRAILING SHIELD STRUCTURE AND METHOD FOR CREATING THE SAME

INVENTOR(S):
Jeffrey S. Lille

ASSIGNEE: HITACHI GLOBAL STORAGE TECHNOLOGIES

SILICON VALLEY IP GROUP, PC
P.O. BOX 721120
SAN JOSE, CA 95172

TRAILING SHIELD STRUCTURE AND METHOD FOR CREATING THE SAME

FIELD OF THE INVENTION

The present invention relates to magnetic heads, and more particularly, this invention relates to a head having a trailing shield structure.

BACKGROUND OF THE INVENTION

In a typical head, an inductive write head includes a coil layer embedded in first, second and third insulation layers (insulation stack), the insulation stack being located between first and second pole piece layers. A gap is formed between the first and second pole piece layers by a gap layer at an air bearing surface (ABS) of the write head. The pole piece layers are connected at a back gap. Currents are conducted through the coil layer, which produce magnetic fields in the pole pieces. The magnetic fields fringe across the gap at the ABS for the purpose of writing bits of magnetic field information in tracks on moving media, such as in circular tracks on a rotating magnetic disk or longitudinal tracks on a moving magnetic tape.

The second pole piece layer has a pole tip portion which extends from the ABS to a flare point and a yoke portion which extends from the flare point to the back gap. The flare point is where the second pole piece begins to widen (flare) to form the yoke. The

placement of the flare point directly affects the magnitude of the magnetic field produced to write information on the recording medium. Since magnetic flux decays as it travels down the length of the narrow second pole tip, shortening the second pole tip will increase the flux reaching the recording media. Therefore, performance can be optimized by aggressively placing the flare point close to the ABS.

FIG. **1** illustrates, schematically, a conventional recording medium such as used with conventional magnetic disc recording systems. This medium is utilized for recording magnetic impulses in or parallel to the plane of the medium itself. The recording medium, a recording disc in this instance, comprises basically a supporting substrate **100** of a suitable non-magnetic material such as glass, with an overlying coating **102** of a suitable and conventional magnetic layer.

FIG. **2** shows the operative relationship between a conventional recording/playback head **104**, which may preferably be a thin film head, and a conventional recording medium, such as that of FIG. **1**.

FIG. **3** illustrates schematically the orientation of magnetic impulses substantially perpendicular to the surface of the recording medium. For such perpendicular recording the medium includes an under layer **302** of a material having a high magnetic permeability. This under layer **302** is then provided with an overlying coating **304** of magnetic material preferably having a high coercivity relative to the under layer **302**.

Two embodiments of storage systems with perpendicular heads **300** are illustrated in FIGS. **3** and **4** (not drawn to scale). The recording medium illustrated in FIG. **4** includes both the high permeability under layer **302** and the overlying coating **304** of

magnetic material described with respect to FIG. **3** above. However, both of these layers **302** and **304** are shown applied to a suitable substrate **306**.

By this structure the magnetic lines of flux extending between the poles of the recording head loop into and out of the outer surface of the recording medium coating with the high permeability under layer of the recording medium causing the lines of flux to pass through the coating in a direction generally perpendicular to the surface of the medium to record information in the magnetically hard coating of the medium in the form of magnetic impulses having their axes of magnetization substantially perpendicular to the surface of the medium. The flux is channeled by the soft underlying coating **302** back to the return layer (P1) of the head **300**.

FIG. **5** illustrates a similar structure in which the substrate **306** carries the layers **302** and **304** on each of its two opposed sides, with suitable recording heads **300** positioned adjacent the outer surface of the magnetic coating **304** on each side of the medium.

It has surprisingly been found that writing transitions to the media at an off-normal axis produces more stable domains in the media. What is therefore needed is a trailing shield structure that alters the fields of flux for off-normal writing.

What is also needed is a method for producing such a trailing shield without damaging the small writing pole.

SUMMARY OF THE INVENTION

The present invention provides the desired benefits described above by providing standard and thin film magnetic head structures for recording and reading, and that is particularly adapted to perpendicular recording and reading. One head structure includes a write head portion for writing data to magnetic media. The write head portion includes a first pole piece with a first pole tip, a probe pole piece having a probe pole tip for emitting magnetic flux from an ABS end thereof, an insulation stack positioned between the pole pieces, at least one write coil embedded in the insulation stack, a shaping layer positioned between the probe pole piece and the insulation stack for focusing flux to the probe pole tip, a trailing shield spaced apart from the pole, the trailing shield causing the magnetic flux to enter the media at an angle from a plane perpendicular to a surface of the media facing the pole, and a return pole piece. A non-magnetic mask layer coplanar to the trailing shield defines the height of the trailing shield.

Preferably, a throat height of the trailing shield is less than a distance from the ABS end of the probe pole tip to the shaping layer. Also preferably, a ratio of a distance between the probe pole tip and the trailing shield, and a distance between the ABS end of the probe pole tip and a writeable layer of the media, is between about 2:1 and about 1:2. In one embodiment, a distance between the probe pole tip and the trailing shield is less than about 50 nm.

In one embodiment, the trailing shield is not directly magnetically coupled to a back gap of the magnetic head structure. In another embodiment, the trailing shield is

coupled to a back gap of the magnetic head structure. In a further embodiment, the return pole is stitched to the trailing shield at a position recessed from the ABS.

The read head portion includes first and second shield layers and a sensor positioned therebetween. The first pole piece may also function as a shield layer for the read portion. However, it is common for the first pole and a shield layer to be separate layers.

A method for forming a head having a trailing shield includes forming a gap layer above a pole, forming a mask above the gap layer, and forming a trailing shield above the gap layer and adjacent the mask, a throat height of the trailing shield being defined between the mask.

In one embodiment, the gap layer is a nonmagnetic metal, and the trailing shield is formed by plating. The trailing shield can also be overplated to a thickness higher than the mask such that the trailing shield covers a portion of the mask. A return pole can be formed such that the trailing shield is positioned between the pole and the return pole. Again, the return pole may or may not be coupled to the trailing shield. Preferably, the mask is not removed from the head.

Brief Description of the Drawings

For a fuller understanding of the nature and advantages of the present invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings.

FIG. **1** is a schematic representation in section of a recording medium utilizing a longitudinal recording format.

FIG. **2** is a schematic representation of a conventional magnetic recording head and recording medium combination for longitudinal recording as in FIG. **1**.

FIG. **3** is a magnetic recording medium utilizing a perpendicular recording format.

FIG. **4** is a schematic representation of a recording head and recording medium combination for perpendicular recording on one side.

FIG. **5** is a schematic representation of the recording apparatus of the present invention, similar to that of FIG. **4**, but adapted for recording separately on both sides of the medium.

FIG. **6** is a simplified drawing of a magnetic recording disk drive system.

FIG. **7** is a simplified schematic representation of the improved recording apparatus of the present invention illustrating a recording head and recording medium combination for perpendicular recording on one side.

FIG. **8** is a side cross sectional view of a perpendicular read/write head structure, not to scale, according to one embodiment of the present invention.

FIG. **9** is a partial side view of a perpendicular write head pole tip region, not to scale, during fabrication of a write head.

FIG. **10** is a partial side view of the perpendicular write head pole tip region of FIG. **9** upon addition of a trailing shield by deposition.

FIG. **11** is a partial side view of the perpendicular write head pole tip region of FIG. **9** upon addition of a trailing shield by plating.

FIG. **12** is a partial side view of the perpendicular write head pole tip region of FIG. **11** upon addition of a return layer.

BEST MODE FOR CARRYING OUT THE INVENTION

The following description is the best embodiment presently contemplated for carrying out the present invention. This description is made for the purpose of illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein.

Referring now to FIG. **6**, there is shown a disk drive **600** embodying the present invention. As shown in FIG. **6,** at least one rotatable magnetic disk **612** is supported on a spindle **614** and rotated by a disk drive motor **618**. The magnetic recording on each disk is in the form of an annular pattern of concentric data tracks (not shown) on the disk **612**.

At least one slider **613** is positioned near the disk **612**, each slider **613** supporting one or more magnetic read/write heads **621**. More information regarding such heads **621** will be set forth hereinafter during reference to the remaining FIGS. As the disks rotate, slider **613** is moved radially in and out over disk surface **622** so that heads **621** may access different tracks of the disk where desired data are recorded. Each slider **613** is attached to an actuator arm **619** by way of a suspension **615**. The suspension **615** provides a slight spring force which biases slider **613** against the disk surface **622**. Each actuator arm **619** is attached to an actuator means **627**. The actuator means **627** as shown in FIG. **3** may be a voice coil motor (VCM). The VCM comprises a coil movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller **629**.

During operation of the disk storage system, the rotation of disk **612** generates an air bearing between slider **613** and disk surface **622** which exerts an upward force or lift on the slider. The air bearing thus counter-balances the slight spring force of suspension **615** and supports slider **613** off and slightly above the disk surface by a small, substantially constant spacing during normal operation.

The various components of the disk storage system are controlled in operation by control signals generated by control unit **629**, such as access control signals and internal clock signals. Typically, control unit **629** comprises logic control circuits, storage means and a microprocessor. The control unit **629** generates control signals to control various system operations such as drive motor control signals on line **623** and head position and seek control signals on line **628**. The control signals on line **628** provide the desired current profiles to optimally move and position slider **613** to the desired data track on disk **612**. Read and write signals are communicated to and from read/write heads **621** by way of recording channel **625**.

The above description of a typical magnetic disk storage system, and the accompanying illustration of FIG. **6** are for representation purposes only. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders.

FIG. **7** illustrates schematically the orientation of magnetic impulses off-normal to an imaginary plane oriented perpendicular to the surface of the recording medium, generally in the manner provided for by the present invention. As mentioned above, it is advantageous to write transitions to the media at an off-normal axis produces more stable domains in the media, as described in N.H. Yeh, J. Magn. Soc. Jpn., v. 21, p. 269 (1997),

which is herein incorporated by reference. The off-normal flux is created by the combination of a pole **702** and a trailing shield **703**.

Similar to the structure recited above with respect to FIG. **3**, the medium includes an under layer **704** of a material having a high magnetic permeability, preferably greater than 100, such as a permalloy material. This under layer **704** is then provided with an overlying coating **706** which contains a magnetic material preferably having a coercivity substantially greater than the under layer **704**. Both of these layers **704** and **706** are shown applied to a suitable substrate **708**, which may desirably be an aluminum alloy disc, although other material such as glass may also be used.

Magnetic lines of flux extending between the poles **702, 710** of the recording head **700** loop into and out of the outer surface of the recording medium coating **706** with the high permeability under layer **704** of the recording medium causing the lines of flux to pass through the coating **706** in a direction at an angle to an imaginary plane perpendicular to the surface of the medium to record information in the magnetically hard coating **706** of the medium in the form of magnetic impulses having their axes of magnetization generally perpendicular to the surface of the medium. The flux is channeled by the soft underlying coating **704** back to the return layer (P1) **710** of the head **700**.

FIG. **8** illustrates a perpendicular read/write head structure **800** having a trailing shield **802** according to one embodiment. Methods for forming the trailing shield will be discussed subsequently.

As shown in FIG. **8**, a residual masking structure **804** can be created and left in the head **800** to allow for the formation of the trailing shield and for the subsequent

fabrication steps to build the remainder of the write head **806**. Note that it is desirable to leave the masking structure **804** in the head **800** to protect the write gap and pole tip, to protect them from subsequent processing (e.g., copper coils).

In this embodiment, a read head **808** is formed first. The read head includes a first shield layer **810**, a sensor **812**, and a second shield layer **814**. A pole **816** is formed above the first shield layer **810**. A coil structure **818** and insulation layers **820, 880** are formed above the first pole layer **816**. A flux shaping layer **824** is formed above the pole layer **816**. A probe pole tip **826** is formed above the flux shaping layer **824** and extends to the air bearing surface (ABS) **888** of the head **800**. The shaping layer **824** magnetically connects the magnetic flux from the back gap **884** to the pole tip **826**. The probe pole tip **826** directs the flux into the media to perform the write function. The flux returns through the media to the return pole **890**. The pole tip **826** is preferably a ferromagnetic structure with a high magnetostriction, typically CoFe, NiFe, or laminated layers (CoFe, nonmagnetic layer, CoFe, nonmagnetic layer, etc.)

A nonmagnetic gap layer **828** is formed above the probe pole tip **826**. Exemplary materials for the gap layer **828** are alumina or a nonmagnetic metal such as Rh, Ru, etc. As a note, there is a need for an insulator above the coil **818** at the top surface **898** to electrically isolate the coil from the ferromagnetic pole layers. A masking structure **804** of conventional materials such as photoresist (oxide, nitride, silanated resist, etc.) is formed above the gap layer **828**. The trailing shield **802** is formed above the gap layer **828** and the masking structure **804**. The trailing shield **802** is preferably constructed of a soft magnetic material, and should have a high magnetic moment. A preferred material for the trailing shield **802** is NiFe and alloys thereof.

The throat height of the trailing shield **802** is defined between the masking structure **804** and the ABS. The trailing shield **802** should have a throat height that is much less than the distance from the shaping layer **824** to the ABS end of the pole tip **826**. Preferably, the throat height of the trailing shield **802** is less than about 80%, and more preferably, less than about 60% of the distance from the shaping layer **824** to the ABS end of the pole tip **826**.

Also, the thickness of the gap layer **828** between the pole tip **826** and the trailing shield **802** is preferably roughly equal to the distance from the pole tip **826** to the soft underlayer of the media, though a ratio of the gap layer **828** thickness to the distance from the pole tip **826** to the soft underlayer of the media can be in the range of about 1:2 to about 2:1. An illustrative thickness of the gap layer **828** can be about 35 nm or less, but will scale with the dimensions of the pole tip **826**, the dimensions being the track width and thickness of probe pole tip **826**. Preferably, the thickness of the gap layer **828** will be less than about 50 nm for a track width on the order of about 0.1 microns or less.

One advantage provided by the trailing shield **802** is that because the bits in the media are written on the trailing edge of the pole tip **826**, the trailing shield **802** bends the magnetic flux lines. More particularly, the magnetic field that comes out of the probe pole tip **826** enters the media at an off-normal angle, which may help write more stable bits in the media.

An outline of a perpendicular write head pole tip **826** region is shown in FIG. **9**, where the separation of the trailing shield **802** and the pole tip **826** is a gap of non-magnetic material. In order to form the trailing shield **802**, a masking structure is formed above the write gap **828**. The height of masking structure (**HM**) is preferably

substantially greater than the distance from the shaping layer **824** to the ABS. For instance, the height can be greater than about 125% the distance from the shaping layer **824** to the ABS. The reason for the tall height of the masking structure **804** is to prevent leakage of the flux into the trailing shield **802** before it reaches the ABS. A preferred height of the masking structure **804** is about 0.5 microns or more.

The masking structure **804** is preferably formed of a material that can remain in the head, such as an oxide, nitride, silanated resist (Si-containing resist) such as HSQ (hydrosilsesquioxide), etc. The mask is patterned and possibly shaped via reactive ion etching (RIE).

As shown in FIG. **10**, the trailing shield **802** of NiFe other ferromagnetic material is deposited over and/or around the mask. For instance, if the trailing shield **802** is a sputter deposited magnetic material, the trailing shield **802** will encapsulate the masking structure **804**.

FIGS. **11-12** depict a method of forming a trailing shield **802** by plating. As mentioned above, the gap layer **828** between the pole tip **826** and trailing shield **802** must be nonmagnetic, e.g., of alumina or some metal such as Rh, Ru, etc. Rh and Ru are preferred because they are very conductive, and the oxide of Ru is electrically conductive so it can be plated on.

Again, a masking structure **804** is formed, preferably of a material that can remain in the head. See FIG. **10**. The structure is then placed in a plating solution and the trailing shield **802** is formed by plating, resulting in the structure shown in FIG. **11**. The trailing shield **802** may be overplated, such that it "mushrooms" over the edge of the masking structure **804**. While the trailing shield **802** can be allowed to float, it is preferable to

ferromagnetically connect the plated trailing shield **802** structure to the rest of the head. As shown in FIG. **12**, the trailing shield **802** is stitched to the head by a photolithographic lift off or, as shown, forming a return layer **1302** by plating more NiFe to the plated structure. The return layer **1302** extends back to the return pole **816**. Note that the location and shape of the return layer **1302** can vary, but it is preferably stitched to the return pole **816**.

There has thus been described a novel head structure and methods for forming the same. One advantage provided by the present invention includes allowing trailing shield edge definition to be defined with a thin resist process. Another advantage is that the edge of shield thickness is determined by the thickness of the transfer material. Yet another advantage is that the processes disclosed herein allow a thin trailing shield **802** to be fabricated without damaging the pole tip **826**. A further advantage is that the masking material is not present at the ABS surface.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.